ALUMINUM

Project Fact Sheet

Design of Mold Surface Topography

Benefits

- Potential for manufacturing energy savings in the domestic aluminum industry is estimated to be 1.01 trillion Btu per year
- Additional 5-10 percent energy savings from not having to replace the unrecovered metal lost during recycling of the chips
- Potential reduction of ingot scalping by fifty percent
- Annual savings to the domestic aluminum industry could be $22.5 million
- Reduced cost of the scalping operation
- Additional cost savings from a reduction in the amount of metal lost to the furnace skimming operation during scalper chip recycling
- Potential reduction of up to 29 million pounds per year of CO_2, 10 million pounds per year of CO, and 36 million pounds per year of solid waste

Applications

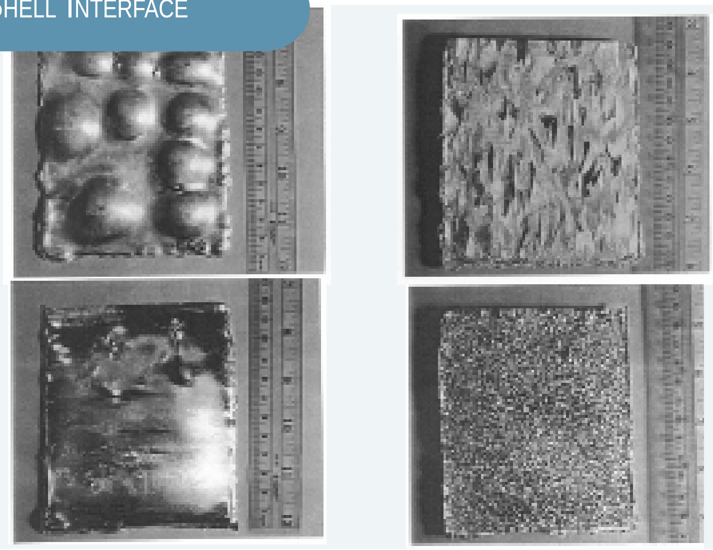
The U.S. aluminum industry is relying heavily on its primary direct chill casting facilities to provide cast ingot of high quality for subsequent bulk forming operations. Due to the emerging global aluminum market, it is imperative that aluminum companies in the U.S. develop advanced strategies to improve the quality of cast ingots at a reduced cost.

Combined Experimental and Computational Approach for the Design of Mold Surface Topography

One of the most challenging problems associated with metal casting is the control of heat extraction through the mold-shell interface during the early stages of solidification. This initial structure critically defines the downstream performance of the cast product. The rate of heat extraction, the evolution of near-surface cast microstructure, and shell macromorphology can be controlled once the proper balance between mold surface area extension and the degree of imperfect wetting at the instant solidification starts is determined. This project's goal is to identify the mechanisms that impact shell surface topography and microstructure and provide design solutions that make it possible to minimize or even eliminate costly post-casting surface milling or scalping which is currently a major barrier to the development of new aluminum casting processes.

This experimental and computational effort is focused on investigating the effects of mold surface topography as well as the physical and thermal properties of the mold (such as wettability of molten aluminum over the mold surface) on the geometric and physicochemical structure of the solidifying shell surface of aluminum castings. The work will integrate heat transfer and deformation analysis; melt flow, contact modeling (tribology), and metallurgical engineering. Finite element techniques will be used to model the ingot surface growth and inverse techniques will be employed to design the mold surface topographies that lead to desired morphologies at the freezing front surface. The mold surfaces will be characterized in terms of groove taper, depth, pitch, and land roughness.

Mold-Shell Interface



Top shows non-uniform front and undesirable columnar grain structure on flip side of ingot, respectively, due to smooth mold surface. Bottom shows parabolic front and desirable equiaxed grain structure on flip side of ingot, respectively, due to sand blasted mold.

Project Description

Goal: The goal of this research is to develop computational and experimental models that can be used to design mold surface topographies for control of the shell surface and subsurface morphologies.

Progress and Milestones

- Generate aluminum castings under controlled laboratory conditions with characterized surfaces.
- Develop analytical models to characterize the microstructure of the solid shell.
- Identify the mechanisms that impact shell surface topography and microstructure and demonstrate that mold topographies can be used to design desired shell surface morphologies.
- Develop finite element models (FEM) to demonstrate the effects of mold topographies on the shell growth and understand the physicochemical and micromechanical mechanisms that control the evolution of the surface structure.
- Develop FEM models to compute the sensitivity of the shell surface morphology with respect to the mold surface topography and other process parameters.
- Develop computational design models that lead to optimum mold topographies and cooling rates for control of the shell surface morphology.
- Use innovative experiments to refine and compare the accuracy of the mathematical models.
- Suggest new aluminum casting processes based on the results of this research.

Commercialization Plan

The technology developed within this project will be made available to the aluminum community through journal publications and/or technical presentations. Industry will incorporate this knowledge to facilitate commercialization.

Mold Surface Topographies

Casting mold surface topographies can be tuned to produce required surface features and microstructural properties of aluminum ingots. Mold surface topographies, which consist of unidirectional and bidirectional groove textures, shall be generated using contact and non-contact techniques to elicit a radiator-like effect at the mold-casting interface.

Project Partners

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